WEATHER ON TARGET

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LONG-TERM GOALS

Because Navy and Marine Corps personnel operate over large, often remote, regions and undergo frequent rotational assignments, they need well-developed tools that can be used to supplement basic meteorological skills with local information and knowledge for specific regions. Our long-term goal is to develop enhanced automated local analysis and prediction tools to provide an essential ingredient to tactical success in Strike, Surveillance, and Littoral Warfare Joint Mission Areas.

OBJECTIVES

The objective is two-fold: to develop automated analysis and forecast tools to improve on-scene weather forecaster knowledge of localized weather conditions, and to utilize conventional and remotely-sensed data to provide nowcasts and forecasts of key meteorological parameters that are needed by the warfighter. While today's forecasters rely heavily on numerical analyses and forecast model guidance, and the skill of those models is constantly improving, the models cannot at this time satisfy all of the warfighter's requirements. In some cases, the warfighters may need meteorological parameters, such as visibility, that are not produced directly by existing operational models. In other situations, the model analysis or forecast may be improved upon by applying specific, localized knowledge of typical atmospheric patterns and behavior to the interpretation of observations and/or model products. Improved nowcasts and forecasts of parameters such as wind, visibility, and cloud-base height in the battlegroup arena will yield payoffs in terms of increased mission success and in cost savings from fewer weather-related aborted missions.

APPROACH

Our approach is to attack the problem of enhancing local analysis and forecast skill from several avenues, since the optimum technique may depend on the particular weather parameter of interest. One obvious way to make up for numerical model deficiencies is to look for ways to improve the model. There are many ongoing efforts within NRL that are working on that approach, and the new high-resolution nonhydrostatic models hold great promise for being able to analyze and predict cloud base height, for example, which previous models could not. But even these highly sophisticated models, such as the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), do not predict visibility. However, if we integrate an aerosol process model into a three-dimensional meteorological mesoscale model such as COAMPS, we can provide a more accurate description and prediction of horizontal variations of visibility and EO wave transmission. Initially, we will conduct sensitivity studies to better understand the characteristics of the aerosol model and the mechanics of coupling to COAMPS, before fully integrating the aerosol model directly into COAMPS. Finally, we

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will evaluate the coupled system by comparing the model results with observational data collected in field experiments. As part of these tests, we will apply the mesoscale/aerosol model to studies of dust storms in the Persian Gulf area. From these studies, we first hope to reproduce the observed characteristics of the specific synoptic conditions leading to the dust storm, which can then be generalized into a set of forecasting rules (or expert system) to further aid local forecasters concerned with such events.

A useful approach to encapsulate traditional man-in-the-loop weather forecasting expertise and experience into software form is by using expert systems. This type of technology is particularly applicable in areas subject to very localized weather events where the numerical models may not have enough data, resolution, or skill to capture the conditions leading to the events. MEDEX (see Progress, below) is a perfect example of using this technology.

Another approach among AI technologies having great potential for meteorology is computer vision. As an example, while numerical models provide fairly accurate estimates of tropical cyclone tracks, they are not very skillful when it comes to analyzing and forecasting tropical cyclone intensity. So, this task is still conducted manually by typhoon duty officers, and they are often lacking all the information they need to make an accurate assessment. We will use computer vision to develop an automated classifier for tropical cyclone intensity. In this effort, we will leverage a database that was developed for other remote sensing projects at NRL; this database relates Special Sensor Microwave/Imager (SSM/I) imagery to the human classification of tropical cyclone strength. Special vision features will be developed to isolate the particular tropical cyclone characteristics that are associated with storm intensity, and the skill of the automated classifier will be evaluated.

WORK COMPLETED

The Mediterranean expert system MEDEX was completed. MEDEX provides forecasting assistance to predict the gale-force onset and cessation for seven major wind events in the Mediterranean region: levante, westerly, mistral, bora (Adriatic), bora (Aegean), etesian, and sirocco, with separate rule bases for the summer and winter. Also, an automated method for distinguishing between five different 500 mb flow types, an important decision point in MEDEX, has been completed.

Computer vision techniques are being used to develop an automated classifier for tropical cyclone (TC) intensity using SSM/I imagery (Bankert and Tag, 1997). Special vision features have been developed to isolate TC characteristics associated with storm intensity.

The one-way coupling (dynamic model drives aerosol model) of the aerosol model to COAMPS has been completed. The coupled model has been applied to a study of a dust storm in Iran and over the Gulf of Oman and found to reproduce the observed characteristics of the dust storm (Westphal and Liu, 1997). The conditions leading to this dust storm will be generalized (using multiple case studies) into a set of forecasting rules.

RESULTS

MEDEX is unique in that it is a fuzzy expert system, making its use easier for forecasters, as well as producing more robust output. Developed and tested over a two-year winter/summer period, MEDEX produces forecast accuracies comparable to those produced by the regional forecast office, the Naval

European Meteorology and Oceanography Center (NEMOC) at Rota, Spain (Kuciauskas et al., 1997a; Kuciauskas et al., 1997b) . A unique feature, that uses fuzzy logic, accounts for the skill of the user in interpreting user input. A prototype MEDEX was demonstrated at NEMOC and was received favorably. Development of the explanation facility, to provide reasoning behind the output, is ongoing. The MEDEX user interface, as well as a user tutorial, is being developed in 6.4.

Based upon a database of 389 tropical cyclone (TC) images, the latest automated classifier results have RMS and average absolute accuracies of less than 15 and 11 knots, respectively, in the maximum sustained wind speed. As of this date, an additional 200 images TC images are being added to the existing 389 database. A larger database will serve to provide a wider distribution of allowable TC variations, and thus a more robust TC classifier.

Numerical simulations of the dynamics using COAMPS has revealed a strong downslope wind event in southern Iran in the vicinity of a dry lake bed, a likely source of dust. Using the dynamical fields from COAMPS, and assuming the dry lake is a source of dust, a predictive model of dust mobilization, transport and removal has been used to simulate the dust event. The spatial distribution and temporal characteristics are in good agreement with the available observations. The distribution of visible and infrared extinction have been calculated for the simulated dust distribution and reveal strong vertical and horizontal gradients. In addition, the long range transport simulated with the explicit model, and observed in satellite imagery, suggest that the local aerosol concentrations cannot be diagnosed using local conditions, as is done in the Navy Oceanic Vertical Aerosol Model (NOVAM). The simulated time-dependence of the size distribution indicates that the assumption of a constant size distribution or constant ratios between visible and infrared optical properties is also invalid under these conditions.

IMPACT

MEDEX will provide a forecasting tool for the regional forecast center in Rota, Spain. This expert system, including its tutorial, help, and explanation facilities, will be particularly useful as a training aid for newly-assigned forecasters. Because our testing statistics suggest that MEDEX can produce forecast accuracies comparable to those produced operationally, MEDEX may also be used as an aid by experienced forecasters. Our TC intensity algorithm is intended for use at the Joint Typhoon Warning Center as an aid to assist forecasters in properly assigning an intensity to satellite-observed TCs.

The Iranian dust storm case study, when combined with others, will allow development of dust storm forecasting rules built upon an existing knowledge of Shamal forecasting. This approach would have been invaluable to forecasters during the Iranian hostage rescue mission of 1980 (and any future Iranian missions), since reports indicate that the fateful dust storm occurred in the same location and under similar post-Shamal conditions as the SHAREM 110A event.

TRANSITIONS

The MEDEX wind forecasting expert system, including the 500 mb pattern recognition software, was transitioned to 6.4 at the end of FY97.

RELATED PROJECTS

The expert system and computer vision work is coordinated with a parallel research effort being conducted with 602435N funding (ONR direct funding). That work, like the research reported here, emphasizes the use of artificial intelligence and computer vision to automate the identification, interpretation, and prediction of weather parameters important to tactical operations. In particular, in FY98, the ONR component will focus on a new technology called Knowledge Discovery from Databases (KDD); we plan to look for biases in the COAMPS predictions of cloud base height, a key parameter affecting many tactical operations. The work performed under both of these 6.2 efforts is further supported by PE 603207N (6.4) for implementation into an operational product (SPAWAR PMW-185). Other related research (also under PE 603207), funded through Point Mugu, is supporting the development of an expert system (ExperDuct) for the prediction of atmospheric electromagnetic ducting (SPAWAR PMW-185).

The aerosol modeling work is coordinated with an ONR-sponsored "Coastal Aerosol Characterization" project (PE 602435N) in which the data assimilation capability for aerosols will be developed. Other activities related to aerosol modeling work are the 6.1 RO (Coastal Aerosol Processes) starting in FY97, and two 6.4 efforts in EOTDA evaluation and aerosol measurement (PE 603207N).

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